Circular Bulletin 139 July 1955

Tomato Diseases in Michigan

By M. C. STRONG

Agricultural Experiment Station
MICHIGAN STATE UNIVERSITY
of Agriculture and Applied Science
Section of Botany and Plant Pathology
East Lansing, Michigan

CONTENTS

Tomato Diseases in Michigan[1]

By M. C. STRONG

BECAUSE of its high vitamin content and dietary value, the tomato is an important crop wherever it is grown. It is an excellent source of vitamin C and also furnishes vitamins A, B_2, and G, as well as anti-pellagra factor.

In 1954, 12,800 acres of tomatoes were grown in Michigan for processing and fresh market.[2] The value of this crop was $4,073,000 and was surpassed only by onions and cucumbers among all other vegetable crops produced in the state. These figures are exclusive of home gardens where tomatoes are always a popular crop.

About 40 tomato diseases occur in Michigan. Some of these are of major importance and others less so, but they are all factors which reduce the maximum tomato production and waste many hours of labor, both in commercial plantings and home garden.

Diseased plants usually cannot be cured but most diseases can be prevented. The purpose of this bulletin is to describe the common diseases of the tomato and to discuss their control so that growers may be able to identify, and thus combat or prevent them. No attempt is made here to discuss the proper culture of tomatoes. For this information the grower is referred to Michigan State University Extension Folder F-142, "Tomato Growing in Michigan".

CAUSES OF PLANT DISEASES

Plant diseases are of two general types, parasitic and non-parasitic. Parasitic diseases are caused by some living organism which grows and feeds on the plant, causing deleterious changes such as discoloration, wilting or premature defoliation. These changes are specific symptoms and growers should learn to recognize them. Non-parasitic troubles are due to unfavorable environmental conditions such as drought, low temperatures, nutrient deficiencies, or excesses in the soil.

The greater number of tomato diseases are parasitic. These are caused by fungi, bacteria and viruses. Fungi and bacteria are micro-

[1]Contribution No. 55-3 from the Dept. of Botany and Plant Pathology, Michigan State University.
[2]United States Department of Agriculture (1955). *Agricultural Statistics: 1954.* U. S. Dept. Agr.

scopic plants which have no green coloring matter and hence cannot manufacture their own food. They have to obtain their food from other living organisms called hosts, in or upon which they grow, or from dead organic material.

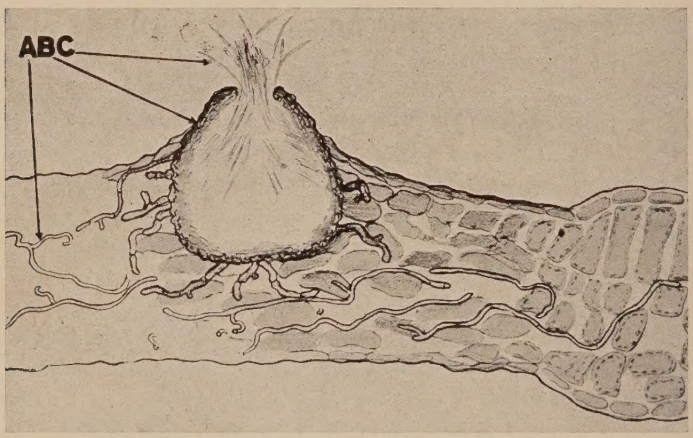

Fig. 1. Drawing of a section through a tomato leaf infected with *Septoria lycopersici* showing: a—fungus threads, b—fruiting body or spore case of the fungus, c—long, needle-shaped spores. Notice that the diseased portion of the leaf is thinner than the healthy part (shown at the right) because of the collapse of the infected cells. The picture is greatly enlarged. At this magnification, the tomato leaflet would be nearly 8 feet across. (Drawing by L. J. Krakover)

Most fungi consist of microscopic, slender, branching threads. After growing for a time and storing some food, a fungus usually reproduces itself by means of minute, seed-like bodies called spores which may be transported by wind, water, insects and tillage implements. The spores are capable of germinating and producing a new fungus plant. Sometimes a week or 10 days is long enough for the production of a new crop of spores which increases considerably the possibilities of the fungus spreading to other hosts.

The bacteria that infect tomatoes are rod-shaped, single-celled organisms even smaller than fungi. They reproduce by dividing into two equal parts. Since it requires only about a half hour for these organisms to mature so that they may divide again, several million bacteria may result from a single source in 24 hours. Plants affected with bacterial diseases usually exude a slimy substance containing millions of

bacteria, or the diseased tissues become exposed by breaking open so that the germs can be spread to other plants by insects, pruning and cultivating tools, or the splashing of rain.

The causal agents of virus diseases are so small that their nature has not been determined by microscopic study, but they are believed to be protein substances capable of multiplying in plant tissue. They are very infectious and a minute amount of juice from an affected plant is able to transmit the disease to healthy plants. Transmission is often accomplished by sucking insects, pruning and cultivating tools, handling diseased plants before handling healthy ones, or by grafting parts of infected plants onto healthy ones. Viruses may be transmitted through seed in some cases or by contaminated soil.

The plant viruses are not usually specific to a particular host but may infect a wide range of hosts. For example, the spotted wilt virus is known to infect 40 species belonging to 14 plant families. A virus often causes different symptoms on different hosts. The virus that causes cucumber mosaic, characterized by mottling and crinkling of the leaves, produces elongation and distortion of tomato leaves and is known as "shoe-string" mosaic. Sometimes two different viruses acting together will produce entirely different symptoms than either one alone, as in tomato "streak".

PARASITIC DISEASES

DAMPING-OFF

This is a universal disease of seedlings caused by a number of common soil-inhabiting fungi (Rhizoctonia, Pythium, and Fusarium) that are able to infect the tender succulent tissues both before and after emergence. Under conditions favorable to infection, considerable losses in stand may result.

Over-crowding and excessive watering of the seed bed are two factors which favor this trouble. Plant seed thinly in rows rather than broadcast, and avoid over-watering.

The most effective method of preventing this disease is by steam sterilization of the seed bed soil (see page 42), flats, tools, etc. After steam sterilization, care should be taken not to recontaminate soil.

When sterilization of the soil by steam is not possible, there are a number of chemical treatments which may be recommended. Maneb or thiram (50 percent) well mixed with seed bed soil at the rate of ¼

oz. per 1 cubic foot will greatly reduce damping-off. Treated soil must be allowed to stand five days before sowing seed. Formaldehyde dust (6 percent) at the rate of 1½ oz. per square foot may be mixed with the top 3 inches of soil before planting. Seed may be sown at once and soil must be thoroughly watered. With all three of these soil treatments, germination is slightly delayed.

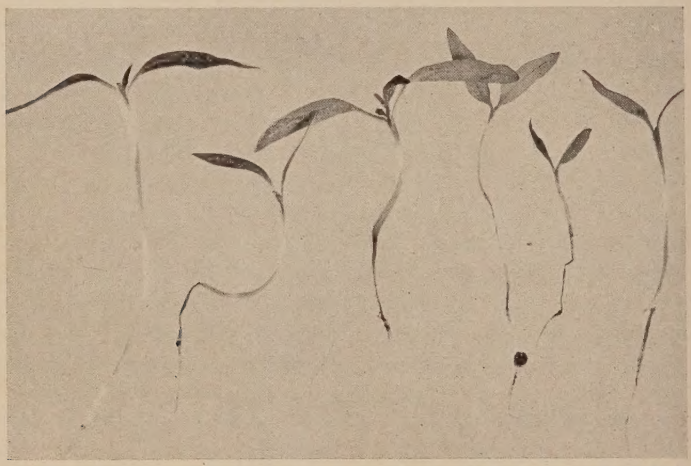

Fig. 2. Damping-off of tomato seedlings. The plant on the left is healthy. Note shriveled stems of the infected seedlings.

Disinfection of the soil with a chemical dust is not to be confused with dust treatment of the seed. Dusting seeds with a fungicide before planting is also an effective method of controlling damping-off. Mercury-containing dusts are not recommended for tomatoes because they often cause injury to the seedlings. Crag 658, Arasan, Cuprocide, and Spergon have been found to be very effective when used as seed dust treatments. Dusting may be accomplished by placing the seed in a fruit jar with the fungicide (at a rate specified by the manufacturer) and shaking until the seeds are well coated. The container should not be more than half full for best results. Screen off excess dust. The fuzzy seed coat of the tomato is particularly well adapted for this type of treatment.

FUSARIUM WILT

Fusarium wilt is found in many tomato growing regions and is a serious disease in warm climates and in the greenhouse. It is common

in the southern part of the lower peninsula, and losses are usually greater in warm seasons.

This disease is caused by a fungus, *Fusarium oxysporium lycopersici* which infects only the tomato but may live in the soil on organic material for years. Infection may occur at any stage of plant growth. The fungus enters through the roots and grows through the water-conducting tissues. When infection takes place in susceptible seedlings, death follows rapidly. When older plants are attacked, the course of the disease proceeds more slowly. The top of the plant wilts and the lower leaves turn yellow and die. The yellowing and loss of leaves proceeds upward in the plant, sometimes on one side of the stem only. The vascular tubes become brown in both stem and petiole. This is a helpful diagnostic feature. If the stem is cut longitudinally the brown discolored area may be observed in the woody tissue.

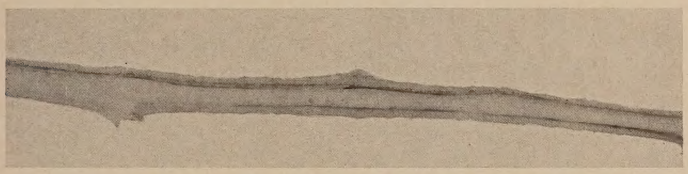

Fig. 3. Longitudinal section of the stem of tomato plant infected with Fusarium wilt. Note dark streaks in the woody tissue.

Older plants usually die about the time fruit matures. The fungus may grow into the fruit and even into the seed, but this is not an important means of spreading the disease.

Fusarium wilt is principally spread by setting diseased plants in the field and by tillage operations and soil working which carries the infected soil from place to place.

In greenhouse and seed bed, this disease may be controlled by steam sterilization of the soil (see page 42). In the field, rotation of crops will prevent a build-up of the fungus in the soil, but will not rid the soil once infested.

Where causal fungus is present, the grower must resort to growing resistant varieties of tomato. Many good ones are available but not all are adapted to our climatic conditions. Marglobe and Rutgers have been in use for the canning crop for years, although they do not possess as high a type of resistance as varieties bred from the red currant tomato *L. pimpinellifolium.*

Pan America was the first variety of this type to be introduced. Now several others are available. Chesapeake, recently released by the University of Maryland, is resistant to Fusarium wilt and to cracking, but is very late (95 days to maturity). Manalucie and Manalee, developed at the Florida station, possess a high degree of wilt resistance but are also very late. Blackhawk, a new wilt resistant variety from the Illinois experiment station, is similar to Marglobe in time required for ripe fruit. Kokomo, Boone and Tipton, all wilt resistant, have recently been released in Indiana. Tipton and Boone were slightly earlier than Rutgers, while Kokomo was later in Michigan trials. Ohio W-R Brookston, a 1954 release from that state, is wilt resistant and earlier than Rutgers while Wiltmaster, produced in Delaware, is similar to Rutgers in earliness.

SEPTORIA BLIGHT

Septoria blight is widely distributed in the tomato-growing regions east of the Rocky Mountains. In wet seasons, when temperatures range from 60° to 80°, this disease is very destructive and may cause serious losses.

The first symptom of Septoria blight is the appearance on the foliage of small, circular, grey spots with a dark border. Later, the entire leaf dies and drops off the plant. The lower leaves are first affected and the disease advances upward, resulting in the progressive defoliation of the plant. This loss of leaves not only reduces the food manufacturing power of the plant and results in a lower yield, but also exposes the fruit to the sun, increasing the possibility of "sun scald". Such exposed fruit usually do not ripen normally, and are orange colored instead of red. These changes greatly reduce the grade of the fruit produced.

Blossoms and stems are also infected by Septoria blight, but fruit is not attacked. Lesions on stems are usually elongated, appearing elliptical rather than round and are slightly larger than those on the leaves.

In the center of these grey spots, tiny black dots, the spore-bearing bodies of the fungus, appear. Hundreds of spores are produced and are spread to other plants by the splashing of rain.

This fungus also infects several weeds related to the tomato—nightshade, groundcherry, horsenettle and jimsonweed. As a control measure, these weeds should not be allowed to grow near seed beds or tomato fields.

Septoria lycopersici overwinters on the infected plant trash left on the ground after harvest. In small gardens, such plant refuse may be

Fig. 4. Septoria leaf spot on leaves and stems. The inset in the upper left-hand corner is an enlargement of a portion of the leaf immediately below, showing the tiny, black fruiting bodies on some of the larger spots.

gathered up and burned. In large plantings, fall plowing is recommended. When plant remains are well buried in the soil, they rot and prevent the overwintering of the fungus.

This disease may be effectively controlled by applications of sprays or dusts containing fixed coppers, zineb or maneb. (See section on spraying and dusting). To date, there are no tomato varieties resistant to this blight.

EARLY BLIGHT

Early blight is caused by *Alternaria solani*, the same fungus which infects potatoes, producing a similar disease. This malady is very common in the central and eastern states, and, in seasons of high temperature and abundant rainfall, may result in serious losses.

Foliage, stems and fruit of tomato are attacked. The leaf spot is brown and often marked by darker, irregular concentric rings. Lower leaves are first affected, turning brown and dropping off the plant. The defoliation proceeds gradually upward until only the top leaves remain. Yield is reduced and exposed fruit are subject to sun scald and similar injuries resulting from defoliation.

This fungus usually attacks fruit at the stem scar, producing a black, semi-circular, rotten spot with concentric markings often covered with a black, velvety growth. Such fruits are unsalable.

Plants may be affected at any stage of growth. On young plants, the stem is often attacked and a dark colored lesion showing concentric markings is produced. This lesion sometimes girdles the stem, killing the plant. When plants with this stem canker are set in the field, they are often broken over by the wind. This stage of the disease is known as collar rot.

Plants suffering from nitrogen deficiency seem to be more susceptible to early blight. For this reason, the disease becomes more severe as many fruits develop and the plants reach maturity. No markedly resistant varieties have been developed. Many of the those considered resistant are merely late, and when they reach maturity their resistance is not maintained.

Spores of this fungus may be carried on tomato seed. Consequently, seed should be disinfected by treatment with mercuric chloride or ethyl mercury phosphate before planting.

The fungus can live on plant material in the soil for some time. For this reason, seedbed soil should be sterilized by steaming, or new soil not previously in tomatoes should be used. In the field, a rotation in which potatoes, peppers and eggplant are excluded should be practiced. Certain weeds related to the tomato, such as horsenettle and night-shade, are susceptible to infection and may harbor the disease.

Fig. 5. Collar rot. The photograph on the right is natural size showing a constricted lesion at the ground level and a secondary lesion above. The photograph at the left is enlarged X3 to show the concentric zoning in the secondary lesion.

Tomatoes should be sprayed twice in the plant bed with a fixed copper or zineb. In the field, plants should also be protected with fungicidal sprays or dusts, beginning when the first fruits are about one-half developed (see page 45) and continuing at 7 to 10 day intervals. During periods of dry weather, treatments may be spaced further apart, but during rainy periods treatments must be applied oftener.

Fig. 6. Photograph above shows concentric zoning typical of Alternaria leaf spot (early blight) on tomato X3. Lower photograph shows infection by Alternaria at the stem end of fruit on plant badly defoliated by this fungus.

PHOMA SPOT AND ROT

The fungus, *Phoma destructiva*, causes a leaf spot and fruit rot of tomato that resembles and may be confused with early blight and *Alternaria* rot. This parasite has been reported in most tomato-growing regions and is very destructive to the winter-grown crop in the south with resulting losses in transit and storage. This disease is of secondary importance in Michigan.

Cool, wet seasons favor the development of the disease, while in dry weather it is seldom prevalent.

Irregular, dark brown or black spots are produced on the foliage. If the disease occurs in the seedbed, many plants may be lost. In the field, the leaf spot may easily pass for early blight. Spores are splashed by rains to the fruit where infection usually occurs at stem scars and cracks. Both green and ripe fruit may be attacked, but the rot progresses faster in ripe fruit.

Fruit infection first appears as a small, circular, sunken, water-soaked spot. As it increases in size, the lesion becomes dark and leathery with a lighter margin. Later, tiny spore-bearing pustules are produced on these spots. As the rot penetrates the fruit, the tissues become dark-colored but remain firm.

Control measures are seed disinfection, crop rotation, and application of fungicidal sprays or dusts in seedbed and field as recommended for early blight. Fruit showing spots should not be packed.

ANTHRACNOSE

Anthracnose is present in most of the tomato-growing areas of the United States and is particularly damaging to the canning crop. This ripe fruit rot is caused by a fungus, *Colletotrichum phomoides*, that lives in the soil and appears to be the source of initial infection. Development of the disease is favored by warm, wet weather.

Wounding is not necessary for infection since this fungus can penetrate the epidermis. Ripe fruit are more susceptible than green ones. In the early stages, anthracnose is characterized by small, circular, sunken spots of about the same color as the surrounding tissue. Later, the center of the lesion becomes dark brown or black, often with concentric rings. Pink or cream-colored spore masses are produced in the dark zones. These spores are splashed by rain to other fruits where

new infections are set up. In warm, wet weather, the spread of disease may be considerable. The rot penetrates deeply into the fruit, spoiling it for market.

Fig. 7. Tomato anthracnose, a shallow, circular spot with dark center, occurs only on ripe fruit.

Rotation is important in the control of Anthracnose, 4 years being the recommended time lapse between tomato crops. Among the newer fungicides, ziram (zinc dimethyl dithio-carbamate) offers effective control. (See section on spraying.)

LATE BLIGHT

Late blight is common in the southeastern and Gulf States, causing small losses. In the northern states, it usually does not appear until the latter part of July. The seriousness of this disease depends on weather conditions; wet, cool periods favoring its development and spread. The disease may occur in greenhouses when the temperature is kept too low.

This disease is believed to be identical with the late blight of potato caused by a fungus, *Phytophthora infestans.* Dark, water-soaked areas are produced on leaves and stems. A badly infected plant resembles one killed by frost. A white downy growth appears on the underside of the leaf, bearing the spores which spread the fungus to other plants. A rot is produced usually beginning near the

stem end of the fruit and spreads around the surface faster than it penetrates into the interior. The rotted area becomes brown with a

Fig. 8. Late blight. Dark brown or black areas on leaf and stem appear like frost injury. On the fruit, a brown discoloration occurs often covered with a downy white growth.

firm, wrinkled outer portion and is often covered with the downy white growth bearing the spores.

Rotting of the fruit is often serious in the transportation and marketing of tomatoes. Fruits picked from infected plants often show no evidence of injury at the time of packing but develop rot during transit.

Though late blight is of little importance during seasons of normal temperature and moisture conditions, it must be recognized as a potential danger to the tomato crop. When temperatures range between 50° and 80° F. with abundant moisture, this fungus is able to kill plants very rapidly and spread over entire fields in a few days. High temperatures and low moisture check the spread of late blight.

The fungus does not overwinter in the soil but lives in infected potato tubers which develop this disease when planted. The initial infection on tomatoes may come from nearby potato fields and the disease is gradually spread over large areas by windborne spores. The blight warning service lets growers know when the disease is present in an area and when conditions are favorable for its spread. There are no satisfactory resistant varieties as yet.

Late blight may be controlled by spraying with a fixed copper fungicide, or with the organic fungicides zineb or maneb. Bordeaux mixture has advantages in lasting qualities over these sprays but has a deleterious effect on fruit set. If late blight did not appear until after a good crop had already set, bordeaux mixture would be a preferred treatment because it would not require as frequent application. Spraying is usually more effective than dusting because better coverage is obtained. However, with proper equipment dusting may be satisfactory. (See pages 45-47.)

BUCKEYE ROT

Buckeye rot is caused by a common soil-inhabiting fungus, *Phytophthora terrestris*. Fruits in contact with the soil are usually attacked, although rains may splash the fungus onto fruits above. This fungus can penetrate the unbroken skin of either green or ripe fruit, and is favored in its development by periods of warm, wet weather.

A greyish-green or brown water-soaked spot appears and enlarges rapidly, usually developing a wide zonate marking of chestnut brown. Green fruits remain firm but soften as they ripen. Eggplant and peppers are also susceptible.

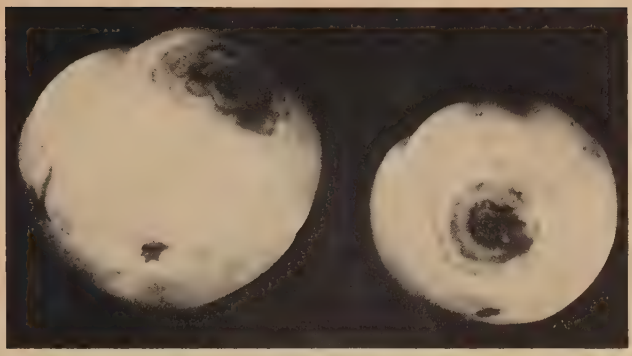

Fig. 9. Buckeye rot. The concentric markings are chestnut brown.

Good soil drainage will reduce losses from this source. In small plantings, staking the plants to keep the fruit off the ground is recommended. A straw mulch may also be used to keep fruit from contact with the soil and to prevent soil splashing during heavy rains.

LEAF MOLD

Leaf mold is a serious disease of greenhouse tomatoes but is seldom important in the field. It is caused by fungus, *Cladosporium fulvum*, which attacks the lower leaf surface producing a velvety spot, olivaceous to purple in color. Spores are abundantly produced on these spots. From there, they are blown or splashed to other plants, starting new infections.

Affected leaves turn yellow and die, thus reducing the food manufacturing power of the plant and consequently the yield of fruit. The fungus also may infect blossoms and reduce the number of fruit set.

The development and spread of leaf mold depend entirely on humidity. If humidity is kept below 80 percent by proper ventilation and air circulation, the disease is thereby controlled. On bright days, rapid transpiration from the leaves increases the humidity of the adjacent air, making conditions ideal for the growth of the fungus. In greenhouses where good ventilation has not been provided by construction, forced ventilation by electric fans has proved effective. Overcrowding of plants should be avoided, and pruning the lower leaves will increase air circulation.

Fig. 10. Tomato leaf showing Cladosporium leaf mold on the under side. (Photograph by W. K. Makemson.)

A distribution of heating pipes throughout the greenhouse has helped some growers to control leaf mold. One steam pipe is placed near the ground between every other row of plants. The alternate space between the rows is slightly wider and is used as the runway. This arrangement of pipes gives a more uniform distribution of temperature and prevents condensation of moisture on the lower leaves of the plant.

In spring and fall, it is necessary to heat the greenhouse at night to avoid a considerable drop from daytime temperatures. This will

prevent condensation of moisture on the leaves of plants and thus help control leaf mold. Surface irrigation should be employed rather than overhead sprinkling when the disease is present in the greenhouse.

Many kinds of sprays have been tried in an attempt to control leaf mold. Some have proved ineffective and a few have injured the foliage or left an undesirable residue on the fruit. Among the fungicides tested, zineb (zinc ethylene bis dithio carbamate) has proved satisfactory where it could be applied thoroughly, the difficulty being to get the spray onto the underside of the leaf.

The development of resistant varieties of tomatoes as a control of leaf mold has been held back by the physiologic specialization, or development of new races, by this fungus. Globelle, a pink-fruited variety, and two red-fruited varieties, Bay State and Vetomold, have been introduced, but none of them are resistant to all races of the fungus. F1 hybrid varieties may be the solution to this problem.

SCLEROTINIA STEM ROT

This disease is characterized by the formation of a brown canker on the stem near the soil surface. The canker may reach 6 to 8 inches in length and is usually covered by a white, downy growth. The top of the plant wilts due to a reduction of water supply from the roots, and the plant eventually dies. The pithy interior of the stem becomes filled with small, hard, black bodies called sclerotia which are the hold-over stage of the causal fungus. The woody tissues of the canker shred apart, allowing the sclerotia to become scattered in the soil (Fig. 11).

The causal fungus, *Sclerotinia sclerotiorum*, is able to attack many host plants including lettuce, celery, carrots, beans, and some ornamental plants. The disease is not common on tomatoes in the field, but has occurred following crops of carrots and beans which were infected.

In the greenhouse, this fungus often builds up in the soil following lettuce, which is commonly attacked, and is called "lettuce drop". The fungus enters the host plant through wounds (in the case of tomatoes, usually a wound made by pruning).

Diseased plants should be removed and destroyed before the sclerotia have scattered in the soil. Between crops, the fungus may be eradicated from the soil by steam sterilization or chemical treatment.

GREY MOLD

Grey mold is caused by a fungus, *Botrytis cinerea*, and occurs only in the greenhouse. This fungus produces a common disease on lettuce

Fig. 11. Sclerotinia stem rot. Notice the cracking of the stem and the white fungus growth on the lower part of the lesion.

and, as tomatoes often follow the lettuce crop, they may also be affected.

This fungus attacks tomato stems at a leaf scar and produces a lesion which may entirely girdle the stem. Fruits are often attacked when petals or styles do not fall off but die still attached. The fungus starts to grow on the dead tissue and then proceeds into the living tissue, causing a fruit rot. The fungus produces a powdery, grey mass of spores on infected portions of the fruit.

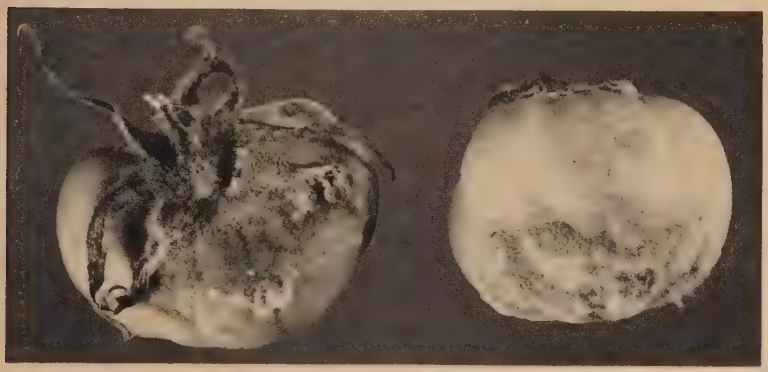

Fig. 12. Grey mold (Botrytis rot) showing grey downy growth on the rotten spot. Infection may occur at either stem or blossom end.

High humidity is necessary for this fungus to develop. The best method of control is to keep the humidity as low as possible by proper ventilation and to prevent night temperatures from dropping below 65°. (See discussion of tomato leaf mold.)

SOIL ROT

Soil rot of tomato usually occurs when the fruit is in contact with the ground and is caused by a common soil-inhabiting fungus, *Rhizoctonia solani*, which also causes damping-off of seedlings.

The fungus may enter either through wounds or the unbroken epidermis. It produces a brown spot with characteristic, narrow-zoned markings of reddish-brown and tan. The spot may be an inch or two in diameter and the center often cracks open. This spot is easily distinguished from buckeye rot by the color and narrowness of the zoning.

This rot occurs more frequently on poorly drained soils and in wet seasons. In small plantings it may be avoided by staking the plants, or mulching so that fruit are not in contact with the soil.

BACTERIAL DISEASES

BACTERIAL WILT

Bacterial wilt, often called southern wilt, affects a wide range of host plants and is very destructive in the southern states. It has never been known to occur in Michigan except on plants imported from the south.

The disease is caused by *Pseudomonas solanacearum*, a common soil inhabitant in warmer climates, but one that does not live over winter under our normal conditions.

Affected plants wilt quickly without discoloration of the foliage. The woody portion of the stem becomes blackened, and the pith decays. Cut stems exude a greyish, slimy material which distinguishes this disease from other wilts.

When infected plants are discovered in a field, they should be removed and destroyed. Do not replant in the same place where diseased plants were removed.

BACTERIAL CANKER

Bacterial canker is caused by *Corynebacterium michiganense* and is the most serious bacterial disease in Michigan. Both field and greenhouse tomatoes may be attacked.

This disease is characterized by a progressive wilting from the lower leaves upward. As the leaflets wilt and turn brown, the petioles remain attached to the stem. Often only the leaflets on one side of the petiole, or the leaves on one side of the stem, are affected at first. The pith becomes yellow and granular, and cavities develop in it.

On the stems, yellow streaks appear which later break open, forming the cankers which give this disease its name. From these cankers, the causal bacteria are spread to fruit and to other plants by the splashing of rain. On the fruit, a characteristic spot known as "birds-eye spot" is produced. It is small and shallow with a rough, brown center surrounded by a white halo (Fig. 13).

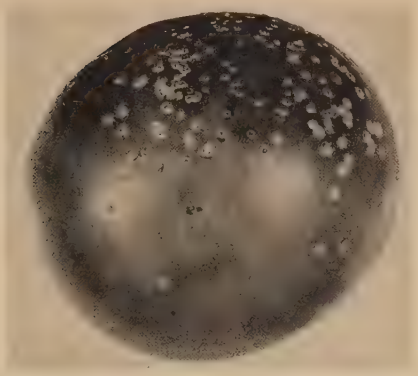

Fig. 13. Bacterial canker on tomato fruit, sometimes called "bird's-eye spot". Notice the white halo around every spot.

A plant may be attacked at any stage of growth. When infection takes place in the seedbed, no symptoms may be noticeable at transplanting time, yet death may occur before fruits are set. Bacteria spread through the water-conducting tissues to all parts of the plant including the fruit and the seed.

Since bacterial canker may be seed-borne, growers must be careful about their source of seed. Certified seed produced in regularly inspected fields may be obtained in Michigan. Such seed must meet certain requirements relating to freedom from disease.

This source of infection may be eliminated by a fermentation process in the production of seed. The fruits are pulped and fermented with the juice at a temperature of 70° F. for 96 hours. The fermenting mass should be stirred twice daily. Seeds may then be extracted and dried.

Seeds extracted without fermentation may be freed from bacterial canker contamination by treating in an acetic acid soak for 24 hours at 70°F. Treat wet seed in an 0.8 percent solution of pure acetic acid in water (1 fluid ounce to 1 gallon water) or treat dry seed in a 0.6 percent solution of acetic acid in water (¾ ounce to 1 gallon water). Tie the seeds loosely in a cloth bag and immerse in the solution, stirring to insure wetting all seeds. Treat no more than 1 pound of seed with each gallon of acetic acid solution. Dry seeds after treatment.

Since this organism is able to live in the soil for some time, sterilization of seedbed and greenhouse soil is advisable where the disease has occurred, and a four-year rotation in the field is recommended.

Tomatoes were considered the only host of bacterial canker but *Solanum rostatum*, a weed belonging to the potato family (and variously known as prickly nightshade or buffalo burr) has been found to be susceptible to infection.

Fig. 14. Bacterial spot on tomato fruit. Notice that the scabby, sunken spot does not have a white halo as does the bacterial canker lesion.

BACTERIAL SPOT

Bacterial spot is caused by *Xanthomonas vesicatorium* and may result in serious losses in both pepper and tomato. If present in the seedbed, this disease may kill many plants. When older plants are attacked, a dark, greasy spotting of the leaf occurs which may cause

some defoliation. On immature green fruit, many small, water-soaked spots are produced. These seldom enlarge to more than ¼ inch, but often are close together, forming larger brown, scabby areas. Ripe fruit is not attacked.

The causal organism is spread by infested seed and soil. Seed should be treated with mercuric chloride or ethyl mercury phosphate as described on pages 40-41. Contaminated seedbed soil should be sterilized by steaming, or be replaced by new soil on which tomatoes or peppers have not been grown.

In seedbed and field, the disease is spread by splashing rains or handling wet plants. In the south, where this disease is serious in seedbeds, antibiotic spray treatments have given some measure of control. Agri-mycin, a combination of streptomycin and terramycin at 200 p.p.m. is being tested but not yet recommended. Desired timing and number of applications are yet to be worked out. However, indications are that this, or some other antibiotic spray, will offer good control of bacterial spot.

VIRUS DISEASES

TOMATO MOSAIC

Tomato mosaic is common on both field and greenhouse crops. It is caused by the same virus which causes tobacco mosaic. Symptoms include a light and dark mottling, and a crinkling and twisting of the leaves. If infection occurs in the seedling stage, plants may be stunted. However, when older plants are infected, only a slight reduction in yield may result.

This virus also affects peppers and egg plants as well as many solanaceous weeds (such as groundcherry and horsenettle). It is spread by handling plants and brushing against them, as well as by aphids.

The primary source of infection is often the hands of workers who are also smokers. This virus can live in dry tobacco leaves for a long time and may be present in cigarettes, cigars and pipe tobacco. Workers should not smoke while handling plants, and should wash their hands with soap and water after smoking to destroy the virus.

Young, infected plants in the greenhouse should be carefully removed and destroyed to prevent spread of the virus. Workers' hands should be washed with soap and water after handling diseased plants.

Fig. 15. Tomato mosaic. Notice the mottling and deformation of the foliage.

Do not replant in the same place, as the virus will remain present on the pieces of roots left in the soil and may affect the new plant.

When a greenhouse tomato crop follows directly after a diseased one, there may be considerable soil-borne infection. However, in the field, this is not an important source of disease.

If seeds from affected tomatoes are immediately planted, some infection may result. After a few months, however, seeds from affected plants do not transmit the disease.

Perennial solanaceous weeds near fields and greenhouses may serve as storage reservoirs for the virus and therefore should be removed. Since aphids can transmit the disease, they should be controlled also.

STREAK

When tomatoes become simultaneously infected with both tobacco mosaic and the latent potato virus, a very serious disease known as

Fig. 16. Tomato streak. The spots on leaves are small, irregular and dark brown; on stems, the long, narrow, dark brown streaks give the disease its name; on the fruit, the spots are irregular, greasy, shallow brown areas.

streak results. The symptoms are conspicuous dark brown or black streaks on stems and petioles, and irregular dark spotting of the younger leaves. The diseased fruit show irregular, sunken discolored areas and are unmarketable. The set of fruit is also greatly reduced.

This disease is very infectious and is spread in the same manner as mosaic. Washing the hands with soap and water before handling plants is the best means of control.

POTATO MOSAIC

When the latent potato mosaic virus is transmitted to tomatoes, only a mottling is produced on the foliage. This trouble is not very serious in itself, but is dangerous when combined with the tobacco mosaic virus, since "streak" follows.

CUCUMBER MOSAIC

Cucumber or melon mosaic may be transmitted to tomatoes, causing a stunting of the plant and a malformation of the foliage in which the leaf is suppressed to a long narrow "shoe string". Affected plants set few fruits.

Transmission of this virus is by aphids. Control measures depend on aphid control and the removal of weed hosts such as catnip, milkweed, pokeweed and groundcherry.

SPOTTED WILT

Spotted wilt is a virus disease with a wide host range. It occurs on dahlia, zinnia, aster, chrysanthemum, cineraria, nasturtium, tomato, potato, eggplant, pepper, tobacco, jimsonweed, black nightshade, winter cherry, plantain, celery, spinach, companula, broad bean and arum lily. It is transmitted by the black carnation thrip and the onion thrip.

Symptoms on tomatoes are a bronze spotting of the foliage, accompanied by a stiffening of the leaves and upward rolling of the margins. On green fruits, yellow circular spots about ½ inch in diameter appear with concentric zones of green. On ripe fruit, the zones are pink or red.

The disease is usually not common in the field but occurs in greenhouses where some of the ornamental hosts are also grown. Removal of weed hosts and separation of ornamental hosts from tomatoes are important control measures.

Fig. 17. Spotted wilt on tomato leaf. Many small, dark spots occur on the leaf which often has a distinct bronze color.

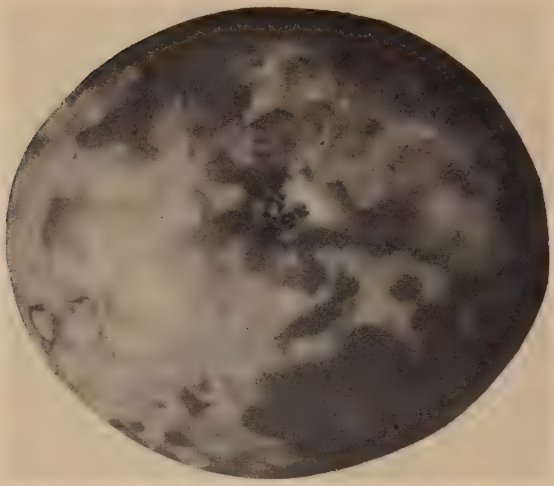

Fig. 18. Spotted wilt of tomato on ripe fruit, characterized by yellow circular markings.

ASTER YELLOWS

The virus that causes aster yellows is infectious on a wide range of hosts including carrot, celery, endive, lettuce, potato and tomato plants, as well as many common weeds and ornamental plants. It is transmitted by several kinds of leaf-hoppers.

While not common on tomatoes, this disease may be severe. Affected plants are stunted and have pale foliage with purple veins. The leaves are stiff with margins rolling upward. Very few fruits are produced.

The occurrence of the disease depends on the source of inoculum, usually a perennial weed host and an abundance of the insect vectors.

DISEASES CAUSED BY INSECTS

CLOUDY OR COTTONY SPOT

Tomatoes sometimes show irregular white spots occuring just below the skin. These blemishes vary in size from very small to half an inch in diameter and may be few or many in number. If the skin is peeled back, the spots are found to consist of a white cottony mass of cells.

This injury is the result of the feeding of stink bugs on the fruit. The spot is not deep and no decay follows. However, fruit so affected is usually rejected by processing companies.

This trouble occurs sporadically and is usually only of minor importance. By the time the spots are noticed, the insects have disappeared and control measures are of no avail.

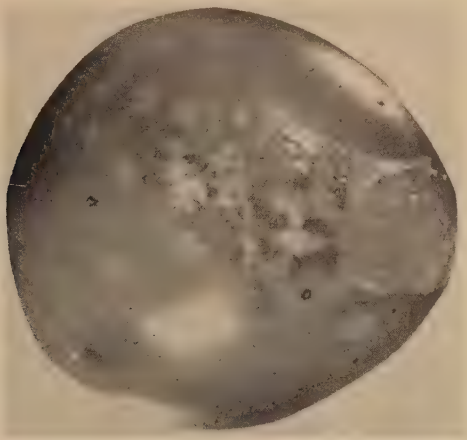

Fig. 19. Cloudy or cottony spots. The epidermis has been laid back to show the cottony clumps of white cells.

TOMATO RUSSET

This relatively new trouble is caused by a colorless, microscopic mite that crawls slowly over the plant. It was first observed in Michigan in 1947 on field tomatoes, and occurred again in 1952.

This pest came to California from Australia prior to 1940, and has since spread across the southern states. Tomato is the principal host, but morning glory and some common solanacious weeds are also affected. Like similar mites, this insect sucks out the cell contents of the surface tissues of stems, leaves and fruits, producing a brown, russeted appearance. Infestation begins near the ground, then progresses slowly upward, destroying the foliage.

On both occasions when the pest appeared in Michigan, the occurrence was on plants imported from the south, and it is not believed

at present that survival over winter is likely under normal conditions. However, it has been observed on greenhouse tomatoes in Indiana and could overwinter in such a manner. Control may be obtained by applications of malathion.

ROOT KNOT

Root knot is a disease of wide distribution in the southern states. It occurs to some extent in lower Michigan, and is a serious greenhouse problem.

Fig. 20. Tomato roots showing nematode galls (root knot).

This disease is caused by a microscopic nematode or eel-worm, *Meloidogyne incognita*. These nematodes penetrate the roots of the plant, feed on the plant juices and increase in size. The mature females produce 200 to 400 eggs which may hatch within the root or externally. The young nematodes, in turn, attack other plants. The root is stimulated to produce swellings or galls which are characteristic symptoms. Wilting, stunting and finally death of the plant result.

Many different crops are attacked by this pest and, once introduced in a sandy soil, root knot is difficult to control. Freezing will not free a soil of this pest. Under Michigan conditions, corn and the small grains (except buckwheat) are usually free from attack and hence may be used as rotation crops to reduce soil infestation.

In the greenhouse and seedbed, root knot is difficult to control because it gets beneath walks and walls where it is hard to reach. Steam sterilization of the soil to a depth of 1 foot is recommended when possible, as described on page 42.

There are a number of soil fumigants which also give good control of root knot. Chloropicrin is the most expensive treatment but also controls some soil fungi and weed seeds. Methyl bromide, ethylene dibromide, the dichloropropane and dichloropropene compounds also will control this pest. (See discussion of soil fumigants on page 44.)

NON-PARASITIC DISEASES

BLOSSOM-END ROT

This trouble, also known as "black rot", "dry rot" or "point rot", is one of the most common non-parasitic diseases of tomatoes and frequently results in considerable losses both in field and greenhouse crops.

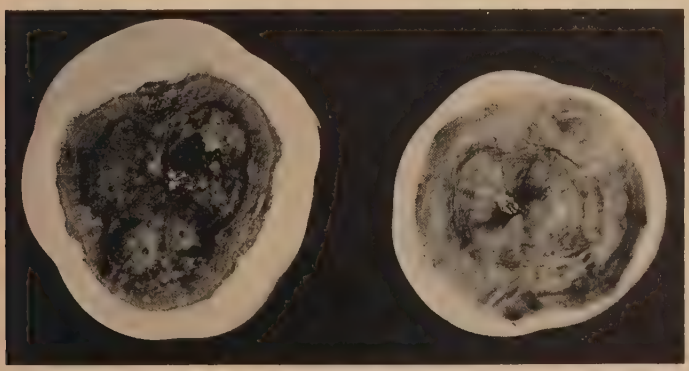

Fig. 21. Blossom-end rot of tomato; the dry, sunken brown spot is actually not rotted until invaded by secondary organisms.

The apical end of the fruit is affected. The first symptom is a small sunken spot about the remains of the style. The spot becomes

dark colored and leathery. It may never increase in size or, if the causal conditions prevail for some time, the spot may enlarge until the apical half of the fruit is involved. Such fruit appears much flattened. Fungi may later invade the affected area and produce a rot, but they are never the initial cause of the trouble.

Blossom-end rot is due to water deficiency during the development of the fruit. In periods of hot, dry weather when rapid transpiration from the leaves occurs, the roots are frequently unable to supply sufficient moisture from the soil and a back flow of water from the immature fruit takes place, causing the collapse and death of tissue at the apical end. The longer the period of drought, the larger the amount of fruit tissue affected.

A number of factors, such as sandy soils and nitrogenous fertilizers, favor the development of blossom-end rot. Sandy soils with poor water-holding capacity may be improved by the addition of organic matter, such as a green crop plowed under. Abundant water supply early in the season and too much nitrogenous fertilizer produce a large, succulent plant requiring a greater water supply than a smaller plant, and consequently more susceptible to this disease.

A uniform supply of water maintained by irrigation throughout the growing season will prevent blossom-end rot from developing. It is better to water heavily once a week than to water daily. The latter procedure results in shallow rooted plants that are susceptible to rapid drying out.

Fertilizers high in nitrogen promote this trouble, while those high in phosphate seem to decrease susceptibility to blossom-end rot.

BLOTCHY RIPENING

Blotchy ripening or grey wall has been a serious greenhouse disease for years, and in the last five years has occurred in some tomato fields, particularly where rotation is not practiced.

This malady is characterized by spots on the ovary wall which never ripen as the rest of the fruit matures, but instead take on a pale, greenish grey color. The vascular bundles in these areas are dark brown or black, and often show through the wall. Anatomical studies show that the parenchyma cells adjacent to the bundles are ruptured and collapsed.

Blotchy ripening is similar to blossom-end rot in that it is related to a water deficiency. However, some nutritional factors also seem to

be involved. Potash deficiency and, to some extent, nitrogen deficiency appear to promote the development of this problem.

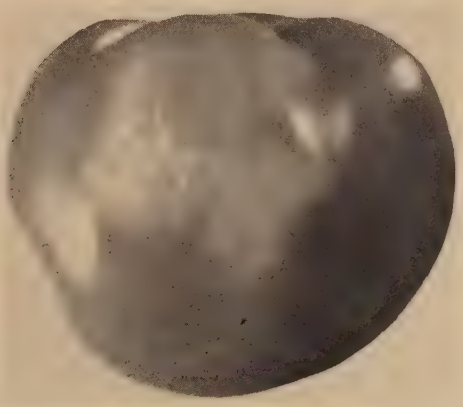

Fig. 22. Blotchy ripening or grey wall. Indefinite spots usually on the shoulder of the fruit appear grey on green fruit and yellow on ripe fruit.

BLOSSOM DROP

Blossom drop is a non-parasitic disease common to both field and greenhouse tomatoes, and one which may cause a serious decrease in yield.

This malady is due to failure in the fertilization of the flower. Many climatic and nutritional factors influence pollenization. Too high and too low temperatures are both unfavorable for pollen germination, with 70° to 80° F. being most favorable. Too much, as well as too little, nitrogenous fertilizer promotes this disease.

In the greenhouse, periods of cloudy weather and short daylight induce this disease because pollen then produced is often incapable of germination. In such cases, the use of fruit-setting hormone treatments or supplimenting the light supply with Mazda lamps has proved beneficial to fruit production.

Some parasitic diseases (e.g., Alternaria, Septoria blight and bacterial spot) also result in loss of blossoms.

LIGHTNING INJURY

Lightning injury during electrical storms sometimes occurs in field tomatoes as in other crops. The affected area is usually circular and may be 30 to 60 feet in diameter. The first symptom is wilting of the whole plant. Plants in the center of the area are usually killed, while those around the edge may recover and grow again.

WALNUT WILT

The black walnut, *Juglans nigra* has an antagonistic effect on many other plants that grow near it, and tomatoes are probably the most susceptible of all species. Tomato plants growing adjacent to black walnut show symptoms of wilting without discoloration, and may later die.

The antagonistic effect of black walnut is caused by juglone, a toxic substance in the roots and shucks. Cutting down walnut trees will be of no immediate benefit because the toxic effect will remain in the soil until all the roots have decayed and disappeared.

Avoid planting tomatoes within 50 feet of black walnut trees. The English walnut (*J. regia*) and butternut (*J. cineria*) do not exhibit this injurious effect.

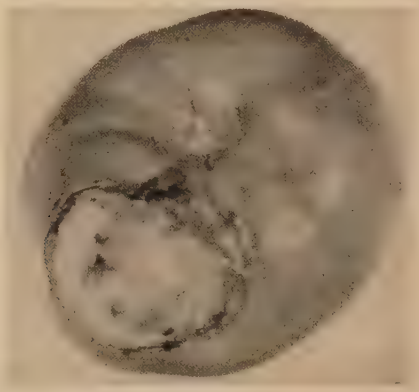

Fig. 23. Sun scald, a tough white area on the side of the fruit exposed to the sun.

SUN SCALD

Varieties of tomatoes with thin foliage, such as Break O'Day, or plants defoliated by Septoria and Alternaria blights are often seriously

affected by an injury called sun scald. A tough, white, sunken spot is produced on the side of the fruit exposed to intense, hot sunlight. These lesions offer avenues of entrance for rot-producing fungi and bacteria, and make the affected fruit unsalable.

TOMATO POCKETS

Pockets and puffiness are descriptive names applied to a defective condition of the fruit characterized by empty, hollow locules. Such fruits are light in weight and appear flattened rather than round. The locules may be entirely empty or the placental tissue and seeds may be partially developed, leaving a hollow space against the outer wall. No decay is involved.

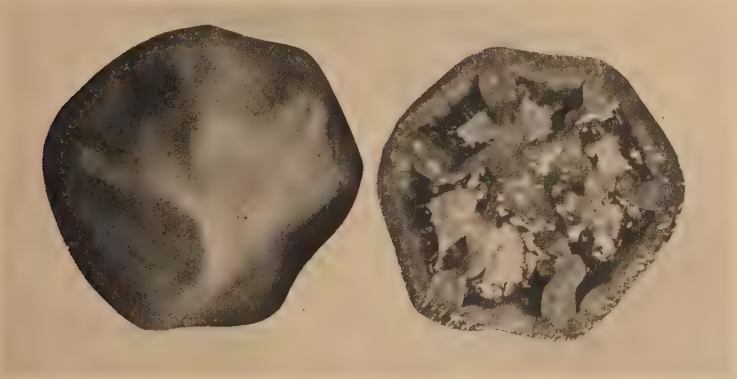

Fig. 24. Tomato pockets. The photograph on the right shows the flattened, irregular exterior of the fruit. The photograph on the left shows the interior of the same fruit with locules only partly filled.

This condition seldom occurs in field tomatoes in Michigan, but frequently results in losses in the greenhouse crop. The cause is not well understood, but appears to be associated with non-fertilization of ovules or failure in development after fertilization. Climatic factors which may bring about or influence this condition are either high or low temperatures, and high or low soil moisture. Nuritional factors also may be involved.

CAT-FACE

This name is given to tomato fruits misshapen by puckered blossom ends with irregular, leathery scars. The condition is due to imperfect

development of certain parts of the fruit, but the reason for it is not well understood. The market value of such fruit is considerably decreased.

Fig. 25. Cat-face, the name given to such puckered mis-shapen fruit.

GROWTH CRACKS

This is a common trouble encountered wherever tomatoes are grown. The cracks may radiate from the stem end and follow the interlocular walls, or be arranged concentrically about the shoulder of the fruit. Such cracks offer avenues of entrance to many fruit rotting fungi and bacteria, and hence may be a source of considerable losses.

Cracking usually follows rainfall or irrigation and is due to the rapid absorption of water by certain tissues. Since the possibility of cracking increases with the age of the fruit, picking green, mature fruit avoids much cracking and ultimately produces a higher grade tomato than by allowing it to ripen on the vine.

INJURY BY WEED KILLERS

Tomato plants are very susceptible to injury by some weed killing materials such as 2, 4-D and alanap. The deforming effects of these chemicals are often mistaken by growers for symptoms of various virus diseases and so are frequently submitted for diagnosis.

Care should be exercised in applying weed killers on other crops so that drift of the spray does not occur. The same spray equipment should not be used to apply fungicides to tomatoes. Plant pots which have come in contact with these materials should not be used for tomatoes, as residues remain present for many months. In some cases, tomato plants may recover from such injury, but the crop usually suffers much reduction.

LEAF ROLL

Leaf roll sometimes accompanies other symptoms of various parasitic diseases. However, leaf roll is often observed in tomatoes when no parasitic disease is present and no injury to the plant or reduction in the crop results. The condition is brought about by high soil moisture and also by pruning.

DISEASES OF UNDETERMINED ORIGIN

GHOST SPOT

Ghost spot is the name given to an indistinct white ring on tomato fruit. The spot is about ¼ inch in diameter, is very superficial and has a minute, brown speck in the center, suggesting the appearance of an insect puncture.

This blemish is not commercially important but may be alarming to growers who mistake it for the birds-eye spot stage of bacterial canker which it slightly resembles. Ghost spot is usually larger and lacks the raised, tan-colored center with broken epidemis that characterizes birds-eye spot.

FRUIT POX

This disease has been reported on field tomatoes from several states. It is characterized by small, dark-colored sunken spots on the young fruit. Sometimes several spots coalesce to form irregular pits. These may occur anywhere on the surface but often are arranged in streaks from shoulder to blossom end. As the fruit matures, these areas may become brown and corky.

These spots render the fruit unmarketable and offer entrance to rot-producing organisms. The cause and control of this disease are at present unknown.

CONTROL MEASURES

When the life history of a parasite is known, its destruction or the prevention of its spread is usually possible. Parasitic tomato diseases may be seed or soil borne, transmitted from related plants or be spread by all three of these methods. Diseases that are carried by seed may be controlled by seed selection from healthy plants and by application of some of the various seed treatments described below. A few of these treatments also protect the seedlings from damping-off, a soil-borne disease.

Soil-borne diseases such as Fusarium wilt, damping-off, root knot and bacterial canker may usually be controlled by soil sterilization or disinfection, and by a rotation of crops.

Diseases that are transmitted from related plants may be avoided by crop rotation, field and seedbed sanitation, control of certain insects and the destruction of weeds.

SEED SELECTION

Since some tomato diseases are seed-borne, the grower should be careful about the source of the seed he plants. Certified seed from inspected fields is available to protect the grower from certain diseases. If the grower wishes to save the seed himself, he must be familiar with the symptoms of disease and avoid saving seed from infected plants.

SEED TREATMENT

Seed treatment is employed to accomplish two different results: (1) to disinfect seed which may be carrying such fungi as *Alternaria* and *Phoma*, or the bacteria which cause canker and scab; and (2) to protect the seed against the soil-inhabiting fungi that cause damping-off. Some seed treatments accomplish both these results, while others have only a single effect.

MERCURIC CHLORIDE

Seeds may be disinfected to free them from surface contamination by soaking in a 1-3,000 solution of mercuric chloride (bi-chloride of mercury or corrosive sublimate) for 5 minutes. This chemical may be purchased in the form of blue tablets or a white powder. One

tablet dissolved in 3 pints of water makes a 1-3,000 solution, a convenient method for treating small quantities of seed.

If the powdered form is used, dissolve ½ ounce in 11 gallons of water. The powder will dissolve more quickly if placed in 1 quart of boiling water, and then the remainder of the water added cold. Either of these solutions will corrode metal and consequently should be mixed in earthenware or wooden containers.

Both solutions are very poisonous, and must be handled and disposed of with care. Treat no more than 1 pound of dry seed in 1 gallon of solution, and use the solution only once. Stir during treatment to insure thorough wetting of seed. Pour seed into a loosely woven cloth bag to drain. Wash seeds in running water for 15 minutes after treatment and spread out to dry. This treatment does not protect seeds against damping off, and they should receive a dust treatment before planting.

ETHYL MERCURY PHOSPHATE

Ethyl mercury phosphate (New Improved Ceresan) is a very effective surface disinfectant for tomato seeds when they are soaked in a 1-1,200 solution (1 ounce in 9 gallons of water) for 5 minutes. Stir during treatment to insure thorough wetting of seeds. Pour seeds into a loosely woven cloth bag to drain, and dry without rinsing. This treatment leaves some residue on the seed which will help combat damping-off. This chemical is corrosive and poisonous, and the precautions mentioned above must be observed. Treated seed should not be stored in airtight containers.

COPPER SULFATE

Copper sulfate (blue vitriol) may also be used as a disinfectant for tomato seeds. Soak the seed for 1 hour in a solution containing 2 ounces of copper sulfate in 1 gallon of water. Drain off the solution, and dry seed without rinsing. Treat no more than 1 pound of seed with 1 gallon of solution. The solution may be used again. This treatment leaves a residue on the seed which is also effective against damping-off.

This chemical is corrosive and very poisonous, and therefore should be used only in earthenware or wooden containers, and must be handled and disposed of with caution.

HOT WATER TREATMENT

A hot water treatment which will accomplish internal as well as external disinfection may be applied to seed. Seeds are soaked in hot water at 122° F. for 25 minutes. The temperature must be carefully controlled with an accurate thermometer, otherwise germination of the seed will be reduced. After treatment, immerse seeds in cold water and spread out to dry. This treatment does not protect against damping-off.

ACETIC ACID

An acetic acid soak is used to disinfect seed contaminated with bacterial canker, and is described in the section on that disease.

DUST TREATMENTS

Dust treatment of seed for control of damping-off is discussed under section on that disease (page 6).

SOIL STERILIZATION AND DISINFECTION

Since many disease-producing organisms can live in the soil and infect crop plants, it is advisable to sterilize or disinfect seedbed and greenhouse soil before planting. This is most effectively done by steam sterilization. However, when this is not possible, certain chemical treatments may be used.

STEAM STERILIZATION

Steam sterilization may be accomplished by means of a steam pan large enough to cover several square feet of area, yet not too large to be moved by workmen. The pan should be made of galvanized tin or iron, and should be about 12 inches deep, with sharp edges so that after the pan is inverted over the soil, it may be pushed down into the soil. This pan is attached to the steam boiler by means of a hose and steam is forced into the soil. The soil should be in a loose, workable condition before steaming is attempted. The steam pan may be moved about until all the soil in the greenhouse has been sterilized. It is necessary that a temperature of 210° F. be attained in the soil beneath the steam pan.

This method has several disadvantages. It requires much labor, the desired temperature may not reach a sufficient depth for complete sterilization of the soil, and there is danger of recontaminating the soil as the steam pan is moved about.

Another method of sterilizing soil with steam is by the use of 4-inch tile lines or 1½-inch iron pipe, perforated on the lower side with ⅛-inch holes about a foot apart. The tile lines or pipe are buried in parallel rows in the soil and connected at one end to a steam line from the boiler. Tile lines laid 18 inches apart and 15 inches deep have proved more satisfactory than lines laid closer together and not so deep. Tile has an advantage over iron pipe in that it does not rust, and consequently will last longer.

The installation of such a system for steam sterilization is expensive, but the results usually justify the cost. Much labor is saved, and complete sterilization of a large area may be accomplished at one time with less danger of recontamination.

Sufficient pressure should be maintained in the boilers to produce a temperature of 210° F. in the soil. If the beds are covered with canvas or building paper, a higher temperature may be produced at the surface of the soil than when the beds are left uncovered. The length of time required depends on the temperature reached. If accurate thermometers are not available, a simple test may be employed. Bury potatoes at various places in the soil. When the potatoes are cooked, the desired temperature has been reached.

FORMALDEHYDE DRENCH

When steam for sterilization is not available, soil may be sterilized by treating with a solution of formaldehyde; one pound formalin (40 percent formaldehyde) to 30 gallons of water. Spread the soil in a layer 6 to 8 inches deep, and pour the solution on at the rate of one gallon to each square foot of soil. Cover tightly with canvas or burlap sacks for 48 hours. After this treatment, the soil must be allowed to air out for about two weeks before any seeds are planted. The soil should be well-forked every day so that all the formaldehyde will be out of the soil before planting.

Flats, benches, soil containers and tools may also be sterilized with formaldehyde solution to avoid recontamination of sterilized soil.

SOIL FUMIGANTS

Volatile soil fumigants are used both in the field and greenhouse to control root knot nematode and some fungi. Many of these do not effect complete disinfection of the soil, but reduce the parasitic population to a point where a crop may be produced.

For treatment with these materials, the soil should be in a loose friable condition; moist—not dry, and not so wet as to be soggy. Temperature of the soil during treatment is important. If below 65° F., the chemicals will not volatilize sufficiently to produce the desired effect. The surface of treated soil must be kept wet to provide a water seal to retain the gas, or a gas-proof tarp or plastic cover must be used. After treatment, the soil must air out for several days before planting. Shallow-rooted crops, such as radish and beets, are safest to use following fumigation.

Chloropicrin (tear gas) treatment requires a 48-hour period for fumigation, and treated soil must be allowed to air out for 2 weeks before transplanting into it. Chloropicrin is unpleasant to handle, is corrosive to metals and cannot be used near living plants. It destroys nematodes and weeds as well as many soil fungi.

Methyl bromide is non-corrosive, less phytotoxic and more volatile than chloropicrin, requiring 24 hours for treatment, and 7 to 10 days for airing out of the soil. This permits planting sooner after treatment. This fumigant is able to kill all stages of the nematode. At the rate of application ordinarily used, it is only a fair fungicide and herbicide.

Ethylene dibromide is a less expensive soil fumigant than the above mentioned materials, but has no fungicidal activity at the rate used for nematode control. When used at dosages of 100 gallons per acre, ethylene dibromide has been found to have fungicidal action.

The D-D mixtures of dichloropropanes and dichloropropenes will give control of nematodes and wire worms at a temperature of 50° F. These fumigants have little or no fungicidal or herbicidal value at dosages sufficient for nematode control. At dosages of 60 gallons per acre, these material have given good control of some soil fungi.

Great care must be exercised in handling soil fumigants. Avoid breathing the fumes. Wash liquids off the skin promptly with soap and water. If the liquid is spilled on clothing, shoes or gloves, remove these garments immediately.

ROTATION OF CROPS

Soil-borne diseases may be controlled in the field by a suitable rotation of crops. By growing crops which are not susceptible to infection, many parasites may eventually be starved out. It is necessary to know which crops to avoid (see special sections on diseases). In general, potatoes, peppers and eggplants should not be grown in rotation with tomatoes. These plants are close relatives of the tomato and are susceptible to many of the same diseases.

SANITATION

Since many of the causal fungi and bacteria of tomato diseases may live over winter on crop refuse, it is advisable to dispose of such debris after the growing season. In small gardens, plant beds and greenhouses, dead plants may be removed and burned. In large areas, deep plowing to put the plant debris well beneath the soil is recommended. This is best done in the fall so that the plants will be well-rotted by spring. In no case should plant refuse be placed on the compost heap, as this might result in introducing a pathogen into otherwise clean soil.

SPRAYING AND DUSTING

Fungous diseases, such as the leaf blights which are spread by windborne or rain-splashed spores, may usually be controlled by protecting plants with fungicidal sprays or dusts. As the plant grows, new surfaces are exposed to infections so that such spray or dust treatments must be repeated every 10 or 14 days during the growing season.

The first and most important spray application is made in the seedbed. As soon as the true leaves appear, apply zineb or a fixed copper spray at the rate of 1 pound metallic copper per 50 gallons of water, and repeat at 10 to 14 day intervals. About two applications are required at this stage.

In the field, defoliating leaf diseases usually do not develop until fruit is set. Unless the early part of the season has been particularly favorable for diseases, the first spray or dust treatment is applied when the first fruit cluster is well developed. From there on, fungicidal applications should be made at 10 to 14 day intervals, or more often if rainy weather prevails. Five or six applications are usually necessary.

Good coverage of the plant is essential to the effectiveness of

either spray or dust applications. Both sides of the leaves must be covered, and the inner leaves treated as well as the outer ones. This requires the use of adequate power equipment.

Many good fungicides are available, but some have certain advantages that make them more desirable on tomatoes.

Fixed coppers give control of the leaf blights but are not effective against anthracnose. Ziram (zinc dimethyl dithiocarbamate) is the most effective fungicide now available against anthracnose, but does not control late blight. Hence, these two fungicides are often used alternately in a spray schedule. Recently it has been found that the two may be combined in the same spray application. Each is used at one half the usual recommended concentration unless late blight threatens. In that case, the full amount of copper should be resumed.

Zineb (zinc ethylene bis dithio carbamate) and maneb (manganese ethylene bis dithio carbamate) are effective in the control of late blight and afford partial control of anthracnose. Captan is not recommended on tomatoes because it often burns the foliage.

Bordeaux mixture is not recommended for early spray treatments because of a deleterious effect on fruit set. However, if late blight appears after a good set of fruit has already been obtained, bordeaux mixture may be safely applied, and is probably the best fungicide available because of its excellent sticking properties.

The value of spray treatments depends on coverage and timing of applications. Number of applications:

copper plus ziram	5 or 6
carbamates	8 or 10

Gallons per acre—125 to 150 early, later 200 gallons.
Nozzles and pressure—4 nozzles per row, 300 to 400 pounds pressure.
Rate of speed of sprayer—Not more than 2.5 miles per hour.
Nozzle disc—At this rate of speed, No. 3 disc will be required at 400 pounds pressure; No. 4 disc at 300 pounds pressure. When more gallons per acre are needed, use next larger disc. Spray when foliage is dry.

Dusting may be as effective as spraying if good coverage is obtained. With ground dusting, 50 pounds per acre are usually required. With airplane dusting, 60 to 70 pounds per acre are recommended. Dusting should be done when there is little or no wind, and when plants are wet with dew.

Timing depends upon weather conditions. During periods of wet

weather, treatments must be applied oftener because the rain washes the fungicide from the leaves. In dry weather, the intervals between applications can be longer.

Whether applications of a fungicidal spray or dust on tomatoes will prove to be a profitable investment depends upon several factors that cannot be predicted. In seasons when fungous leaf diseases are not prevalent, such spray or dust treatments may be a waste of labor and materials. When such diseases are prevalent and serious, fungicidal sprays or dust, effectively applied, will increase production and quality of fruit.

Whether increased production and quality of fruit will be of monetary value to the grower depends largely upon the price of tomatoes and the market served. If tomatoes are grown for a critical market (a processing company or any market where federal grades are enforced), an increase in fruit quality will command a better price. When tomatoes are scarce and the price is high, a moderate increase in production of fruit will bring a greater profit. When the price of tomatoes is low, profits are likely to be less than the cost of applying spray and dust treatments.

The grower is advised to be ready to spray or dust if necessary, but to time such treatments according to rainfall and the appearance of the diseases. Defoliating diseases are usually most severe after the fruit has begun to set. Spray or dust applications delayed until this time will provide effective control of these diseases if the early part of the season has been relatively dry.

SUMMARY OF CONTROL MEASURES

1. Use clean seed and disease-free soil in the seedbed. Disinfect flats, sashes and boards used for seedbeds. Dust seed with a fungicide. Plant seed thinly in rows and do not overwater. Spray young plants in the seedbed with zineb or a fixed copper (at rate of 1 pound metallic copper per 50 gallons of water).
2. Destroy such weeds as jimson, groundcherry, nightshade and horsenettle in the vicinity of seedbed, greenhouse and fields. Watch for diseased plants. Pull up and burn plants showing mosaic as soon as discovered, and wash hands before handling other plants. Spray or dust with fungicides for control of leaf blights and anthracnose, beginning when first fruit cluster is well developed or earlier if season has been rainy.

3. Clean up garden, field or greenhouse when crop is finished. Old vines should be plowed under, or gathered up and burned. Do not allow plant refuse to remain over winter on the ground, and never put it on the compost heap.

4. Use a rotation of crops in which tomatoes, potatoes, peppers and egg plants do not follow one another.

5. Sterilize soil two weeks before setting plants in the greenhouse. Control humidity by heat and ventilation.

KEY FOR THE IDENTIFICATION OF TOMATO DISEASES

A. **Fruit only affected:**

Dark, shriveled spot on apical end ..... Blossom-end rot
Tough white spot on side ..... Sun scald
Hollow, sterile locule ..... Pockets
Misshapen, puckered with scar on apical end ..... Cat-face
Spot with narrow concentric zones of tan and reddish brown ..... Soil-rot
Spots remaining greenish grey, not ripening ..... Blotchy-ripening
Cracks radiating from stem end or arranged concentrically on shoulder ..... Growth-cracks
Small, circular, sunken spots becoming dark at center ..... Anthracnose
Flat white ring with minute brown speck at center ..... Ghost Spot
White irregular blotches just beneath skin ..... Cloudy or Cottony Spot
Large spots with wide, zonate brown markings ..... Buckeye rot
Small, circular, dark colored pits often coalescing, becoming brown and corky ..... Fruit pox

A_1. **Fruit affected, accompanied by other symptoms:**

Grey rot covered with grey, powdery mold ..... Grey mold
Circular yellow markings ..... Spotted wilt
Misshapen with irregular, sunken brown spots ..... Streak
Irregular, dark brown scab-like spots with water-soaked border Bacterial spot
Small, brown, crusty spots with white halo ..... Bacterial canker
Dark, circular, zoned, sunken spots at stem end ..... Early blight
Black, leathery, sunken spot with pimple-like pycindia at center Phoma rot
Rapidly spreading, firm rot, skin wrinkled and discolored, white growth on surface ..... Late blight
Russeted appearance on surface ..... Russet

B. **Symptoms on leaves only:**

Lower leaves rolling upward ..... Leaf roll
Wilting without discoloration on plants adjacent to black walnuts Walnut wilt
Curling with yellow spots above and purple or brown velvety patches below ..... Leaf mold
Narrow, spindling with shoe string appearance ..... Cucumber mosaic
Mild mottle with pale green areas ..... Potato mosaic

B1. **Symptoms on leaves, stems and fruit:**

Crinkled and distorted, mottled with light and dark areas.....Tomato mosaic
Black, irregular spotting on young leaves.....Streak
Bronze spotting on young leaves.....Spotted wilt
Bronzing of entire leaf surface.....Russet
Wilting of tops, progressive yellowing from lower leaves upward.....Fusarium wilt
Wilting without yellowing.....Bacterial wilt
Grey, circular spots with dark border.....Septoria blight
Dark brown spots, concentrically zoned.....Early blight
Dark brown, irregular spots.....Phoma spot
Dark, water-soaked spots with white, powdery growth on under side.....Late blight
Leaflets wilting while petioles remain erect.....Bacterial canker
Stiff, pale yellow with purple veins.....Aster yellows

C. **On stems only:**

Brown canker covered with downy white growth, pith filled with hard, black, irregular sclerotia.....Sclerotinia stem rot

C1. **On stems and other plant parts:**

Brown streaks in woody tissue.....Fusarium wilt
Black streaks in woody tissue, slimy exudate when cut.....Bacterial wilt
Yellow streaks cracking open into cankers.....Bacterial canker
Black streaks on surface.....Streak
Greyish, elliptical spots with dark border.....Septoria blight
Dark brown cankers with concentric markings.....Collar rot (Early blight)
Sunken lesion at leaf scar covered with powdery grey growth.....Grey mold
Wilting or killing of plants in circular ground area.....Lightning injury
Shriveled at ground line, tops wilting and falling over (seedlings).....Damping off

D. **On roots:**

Galls or swellings formed.....Root knot